4.4.2 Analytical Methods

A method of calculating the interference effect of in-band secondary downlinks on the uplinks of CDMA systems has been developed that does not require knowledge of all the transmission parameters needed to perform a link performance budget.[1] Instead, this calculational method employs some of the concepts and techniques of the uplink sharing approach described in Section 5. Specifically, the cited CDMA uplink sharing concept uses a possible limit for each system, i.e., a boundary value for the uplink EIRP areal-spectral density values. This calculation uses the same value (-140dBW/m^2/4KHz) to define the aggregate uplink EIRP of the interfered-with CDMA system as the CDMA proponents used in their proposed uplink sharing analysis.

This analysis starts with a calculation of the ratio of the power density of the potential secondary downlink interferer at the victim satellite receiver relative to the aggregate power density (-140dBW/m^2/4kHz) of all the probable co-polarized primary uplinks. This ratio can be expressed as:

$$I_R/(Io + Ii);$$

where I_R is the interfering power spectral density and (Io + Ii) are defined as the following footnote. This ratio identifies the percentage of noise the secondary downlink interferer would add to the total noise. It is one indicator of the contribution of the unwanted interference to overall system performance.

The second phase of the analysis is to determine the maximum link performance degradation (in Eb/N_T) due to the interfering power. This is accomplished by assuming the victim signal exactly achieves the required

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1 It will be noted that the CDMA applicants have suggested a different approach to the assessment of interference from secondary downlinks. That approach, which provides misleading conclusions, is described in Annex 4.3. Annex 4.3 also includes an analysis that shows why the fundamental premise of this analytical approach provides erroneous assessments.

link performance (E_b/N_T)[2] in the absence of the secondary downlink transmissions. It should be noted that exactly achieving the required E_b/N_T is highly unlikely in real systems, because the system operator will almost surely employ power control to assure adequate performance -- with some margin. Moreover, the granularity of power control techniques will ensure the "exact" E_b/N_T is rarely achieved, and a system operator will generally err on the side of having a positive margin. The anticipated E_b/N_T in the presence of the wanted and unwanted signals is then calculated. The difference between the results of this calculation and the required E_b/N_T value is somewhat higher than the maximum degradation in link performance due to the secondary downlink interferer.

4.4.3. Results of Calculations

Two sets of input information are needed to perform this analysis of interference. These are the parameters of both the interfering and victim systems. The parameters of the potential victim systems are provided in Annex 4.1 in accordance with the most recent information provided by the CDMA applicants' (and Celsat) describing their systems.[3] Annex 4.2 shows the calculation of the secondary downlink EIRP density and that of its associated uplink using the parameters of the Iridium system, as applied for.

The results of the calculations using the above-described methodology are shown in two tables below. Table 4.4-1 shows the effects of the in-band secondary downlink in the backlobe interference scenario described as Case 1 in Section 4.3.2. Table 4.4-2 shows the effects of the in-band secondary downlink in the trans-horizon scenario described as Case 3 in Section 4.3.2.

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[2] E_b/N_T is defined as the ratio of the received energy per bit divided by the total noise density per hertz. The total noise density is the sum of thermal noise, self-interference and noise from other systems, i.e., $N_T = N_o + I_o + I_i$: where N_o=thermal noise density; I_o=the total self-interference noise density: and I_i=the total self-interference noise density from other systems.

[3] It should be noted that in this analysis the CDMA system parameters that are used are those indicated by the applicants. Section 5 of this report adjusts some of these parameters to reflect realistic expectation of implementation.

The first value in each entry in the tables is the maximum degradation in E_b/N_T due to the in-band secondary downlink signals. The second value in each entry in the table is the percentage of the in-band secondary downlink interference density at the victim satellite relative to the total interference density due to primary uplink signals.

Table 4.4-1
In-Band Backlobe Interference Scenario

Primary Interfering Sources	Aries	Ellipso	Globalstar	Odyssey	Celsat
Victim System Alone	0.33 dB 7.9%	0.04 dB 0.9%	0.20 dB 4.6%	0.04 dB 0.9%	0.16 dB 3.8%
Victim System + IRIDIUM Uplink	0.28 dB 6.8%	0.03 dB 0.8%	0.15 dB 3.5%	0.03 dB 0.7%	0.08 dB 1.8%
Victim System + One Other CDMA System, no IRIDIUM uplink	0.17 dB 4.0%	0.02 dB 0.5%	0.10 dB 2.3%	0.02 dB 0.4%	0.08 dB 0.9%
Victim System + 3 Other CDMA Systems, no IRIDIUM uplink	0.09 dB 2.0%	0.01 dB 0.2%	0.05 dB 1.2%	0.01 dB 0.2%	0.04 dB 0.9%
Victim System + 3 Other CDMA Systems + IRIDIUM Uplink	0.08 dB 1.9%	0.01 dB 0.2%	0.05 dB 1.1%	0.01 dB 0.2%	0.03 dB 0.8%

Table 4.4-2
In-Band Trans-Horizon Interference Scenario

Primary Interfer-ing Sources	Aries	Ellipso	Global-Star	Odyssey	Tilted Odyssey	Tilted Odyssey X-Pol	Celsat
Victim Satellite Alone	0.16 dB 3.8%	0.06 dB 0.3%	0.28 dB 6.7%	0.08 dB 2.0%	2.22 dB 66.6%	0.03 dB 0.7%	0.01 dB 0.2%
Victim Satellite + One Other CDMA System	0.08 dB 1.9%	0.03 dB 0.7%	0.14 dB 3.3%	0.04 dB 1.0%	1.25 dB 33.4%	0.01 dB 0.3%	0.00 dB 0.1%
Victim Satellite + 3 Other CDMA Systems	0.04 dB 1.0%	0.01 dB 0.3%	0.07 dB 1.7%	0.02 dB 0.5%	0.67 dB 22.2%	0.01 dB 0.2%	0.00 dB 0.0%

4.4.4 Discussion and Assessment of Calculations

As can be seen from Table 4.4-1, which lists the results of the calculations of the in-band backlobe interference scenario, the effects of the in-band secondary downlinks are negligible in the presence of primary uplinks from three other CDMA systems. For this case, the E_b/N_T degradation is 0.08 dB or less for all applicants and under 0.03 dB for Celsat. This level of change in E_b/N_T may not even be measurable, except with very sensitive measurement equipment. These E_b/N_T changes would cause the usually required 10^{-3} bit error rates to decrease from 0.8×10^{-3} to 0.99×10^{-3}, depending on spreading rate, modulation and coding employed. Moreover, these levels of degradation are well within the granularity of the best power control capability (± 0.5 dBW) proposed by the applicants. This level of degradation in link performance for the short period per day it is likely to occur is insignificant.

The in-band, trans-horizon case, however, shows there is one case where mitigation techniques may be required (see Table 4.4-2). This case is that of a "tilted" Odyssey satellite. In order to provide its desired coverage of only land areas, the current operational plan of the Odyssey system calls for its satellite antenna beams to be tilted. If Odyssey implemented this operational plan, some part of the main lobe of one of its satellite antenna beams may be susceptible to trans-horizon interference from a secondary downlink, depending on planned tilt angles and coverage areas. As shown in Table 4.4-2, operating the Iridium satellite antenna with the opposite sense of polarization to Odyssey's satellite antenna would resolve any tilted antenna interference problem. While this is an obviously desirable design constraint, it may not be possible to achieve in practice.

The potential for interference is minimized further by two additional factors. First, it should be noted that although the frequency, probability and duration of such interference events has not yet been calculated, it is believed this type of trans-horizon interference is not likely to occur very often, considering that Odyssey satellites will only occasionally be tilted at acute angles and that at higher latitudes Iridium satellites will shut down many of their outer cells that are capable of trans-horizon emissions. To the extent it does occur, this case is an obvious candidate for the beam management mitigation technique described in Section 4.5.

Second, it must be noted that this analysis, and most analyses of this type, assume a situation that is extremely unlikely to occur in practice. For example, this analysis assumes the victim satellite and each of the three CDMA systems sharing the uplink interference must be operating at 100% occupancy of available channels at the same time.[4] In one case shown in Table 4.4-1, the total interference noise density of Globalstar and three other systems at the satellite antenna of Globalstar is -195.8 dBw/Hz (26.5×10^{-2} watts/Hz) at 100% occupancy of all four

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[4] Perfect and exact power control for a LEO-MSS system is a practical and probably a physical impossibility because of time delay due to the path length and the granularity of the power control technique. Likewise 100% channel occupancy is not practially realizable because there is always some time between call drop-off and initiation of another call when the channel is unused. In many systems, the practical maximum occupancy is approximately 80%.

systems. The Iridium system would deliver to the Globalstar system antenna 0.306×10^{-21} watts/Hz (-215.1 dBw/Hz), due to the in-band backlobe emissions of its downlink when operating at 100% occupancy. Thus, if the four CDMA systems were operating at a simultaneous, aggregate total occupancy of 98.9% instead of 100%, the Iridium in-band downlinks would cause the total interference noise seen by the victim system to be the same as the 100% occupancy case. In another sense, however, if occupancy were maintained at 100%, the secondary downlink interference would cause the bit error rate to decrease from 10^{-3} to $.9 \times 10^{-3}$, a change which the most sophisticated voice user would not detect. Therefore, when the aggregate simultaneous occupancy of the co-frequency, co-coverage CDMA systems were less then 98.9%, the performance of the victim user signal would be improved over the 100% occupancy case, whether or not the Iridium system in-band downlinks were present.

In summary, the above calculations show that in a static sense there is very low likelihood that in-band secondary downlinks from the Iridium system could cause harmful or even noticeable interference to the uplinks of the currently indicated designs of the CDMA applicants (or Celsat). Techniques described in Section 4.5 are more than adequate to mitigate the few occasions where harmful interference might occur.

4.4.5 Alternative Analytical Method

Another, more direct method of calculating the interference level of the secondary downlink is possible, but it requires more detailed information on the transmission characteristics and capacity claims of the several systems involved. The calculation starts with a determination of the link performance (E_b/N_T) of the desired CDMA signal in the presence of interference noise from its own system and interference noise from other co-coverage CDMA systems sharing the same frequency band on a primary basis (i.e., a link budget calculation for a CDMA system). (The quality of the service provided is monatonically related to E_b/N_T.) The overall link performance is then recalculated including the influence of the potential interferer. The resulting difference in E_b/N_T is caused by the interfering source.

The potential for interference by the secondary downlinks of a LEO-MSS system is not uniform for all co-frequency MSS systems. Moreover, the potential for interference involving LEO-MSS systems is obviously a time-dependent variable. Analyses presented to IWG-1 reported that backlobe emissions from a secondary downlink to the mainlobe of one specific CDMA system were about 0.03% of a day for CONUS. Further analyses need to be performed for additional combinations of systems and potential orbit events (trans-horizon) where this secondary downlink interference should be considered.

Assessing the system impact of the degradation in Eb/N_T is the final step in the evaluation. There are several possible criteria and/or conclusions that could be involved in assessing the impact of the degradation in Eb/N_T. They include:

1) The effect on bit error rate (BER) of the gateway demodulator.

2) The capacity reduction of either the interfered-with or interfering system required to reduce the degradation to acceptable levels.

3) The degradation is not discernable in amount or time duration and can be ignored.

4) The uplink EIRP power control granularity and its standard deviation will mask the performance degradation, especially in consideration of the time duration of the interference event.

5) The impact on Eb/N_T is sufficiently severe to require utilization of one or more of the mitigating procedures discussed in Section 4.5.

4.4.6 Comments

The analyses and assessments above (and in other similar analyses) of the interference effects of in-band secondary downlinks on each of the CDMA systems are static and incomplete. Each of the CDMA applicants' systems has unique geographical, orbit, transmission and signal parameter characteristics. The assessment of the potential for harmful interference on each of these and future CDMA systems must be the subject of individual consultations involving each of the system operators separately. The specific characteristics of each system, such as channel bandwidth, channel occupancy, demodulator capability, constellation design, national authorizations, signal structure, etc., need to be addressed bilaterally in assessing the potential for harmful interference by secondary downlinks. It is clear that new analytical tools and criteria need to be developed and adopted by the FCC and the CCIR to evaluate the interference assessment of the secondary downlinks associated with non-geostationary satellites. Even when such new capability has been obtained, the analyses need to be conducted using complete and accurate system information.

The analysis herein has dealt with the interference situation in the static manner recommended by the CCIR and required by the Radio Regulations for the static environment of geostationary satellites. However, as recognized by WARC-92, the low-earth-orbit satellite situation is not static and use of CDMA techniques in such systems adds another new dimension to the calculational and interference assessment requirements. It is believed the interference effects in a LEO environment will have to be dealt with on a dynamic and statistical basis with interference assessments coordinated on a bilateral basis between system operators. There will be several years in which to develop and adopt the requisite analytical tools.

4.5 Mitigation Methods for Inter-System Interference for the IRIDIUM™ System

Several techniques can be employed to avoid potential "harmful interference" from secondary downlinks to primary uplinks. Since the potentially harmful interference events are predictable in time and space, and relatively short in duration, it will be possible to plan the implementation of these mitigating procedures in advance to avoid harmful interference during the potential interfering event.

4.5.1 Definition of the Mitigation Methods

There are four basic methods of mitigating potential inter-system interference. These methods are shown in Table 4.5-1.

Table 4.5-1
Applicability of Interference Mitigation Methods to Interference Scenarios

	Trans-Horizon	Backlobe/Sidelobe
Band segmentation	√	√
Beam management	√	NA
Frequency management	√	√
Antenna characteristics	√	√

4.5.1.1 Band Segmentation

The primary method of avoiding mutual harmful interference between the Iridium system and other MSS systems is to operate the systems in different frequency band segments. However, as noted earlier, even though the Iridium system and other MSS systems may not operate on a co-frequency, co-coverage basis, because of asymmetrical operating authorizations in different regions, in-band interference events could potentially occur unless their effects were mitigated.

4.5.1.2 Beam Management

Beam management is applicable to the trans-horizon scenario. Beam management would be used to stop transmissions from any Iridium satellite antenna beam towards another MSS systems' satellite, when the skirts of their main beams could intersect. The satellites of the victim system could be either in a geosynchronous or non-geosynchronous orbit. This mitigation technique would reduce the potential interference from the Iridium system to a low level, due only to the sidelobes of a few operating beams.

This beam management technique can mitigate the trans-horizon interference problem without degrading Iridium service in the following manner. The Iridium system has 66 satellites. Each Iridium satellite has 48 antenna beams, thus creating the potential total of 66 x 48 = 3168 beams. However, as the satellites move away from the equator, they come closer together in adjacent planes. Since the coverage area for each satellite is reduced as it moves away from the equator, some of the outer, overlapping beams are shut down. By the time the satellites reach the poles, they will have shut down almost all of their beams. Only approximately 2150 beams are required to cover the world. Consequently, 1018 (3168 - 2150) beams are shut down at any time. The Iridium system is designed to provide service to any geographical location despite loss of an antenna beam. As can be seen from Figure 4.5-1, there is considerable overlap of the Iridium system's globally-managed beams. Because the satellite network has 100% crosslinks between satellites, an outer beam ground area could generally be covered by two satellites since their trans-horizon beam azimuths are approximately 180° from each other.

Moreover, any potential interference event in the trans-horizon case will be very predictable and short in duration. Figures 4.5-2a, 2b, & 2c illustrate the relatively short times when minimum path lengths occur for some representative proposed satellite systems. After the potential interference opportunity has passed, the normal beam management operation may continue.

In equatorial regions, where there is the least Iridium beam overlap, there may be some degradation of Iridium's link margin if it is necessary to switch to a different beam to cover a geographical area, but again, this will be for a very short duration. The Iridium system can accept such momentary degradation, if necessary, to avoid harmful interference to other systems.

4.5.1.3 Frequency Management

Frequency management is applicable to both the trans-horizon and the backlobe/sidelobe scenarios. This technique involves managing the frequencies used by the Iridium system so that no harmful interference

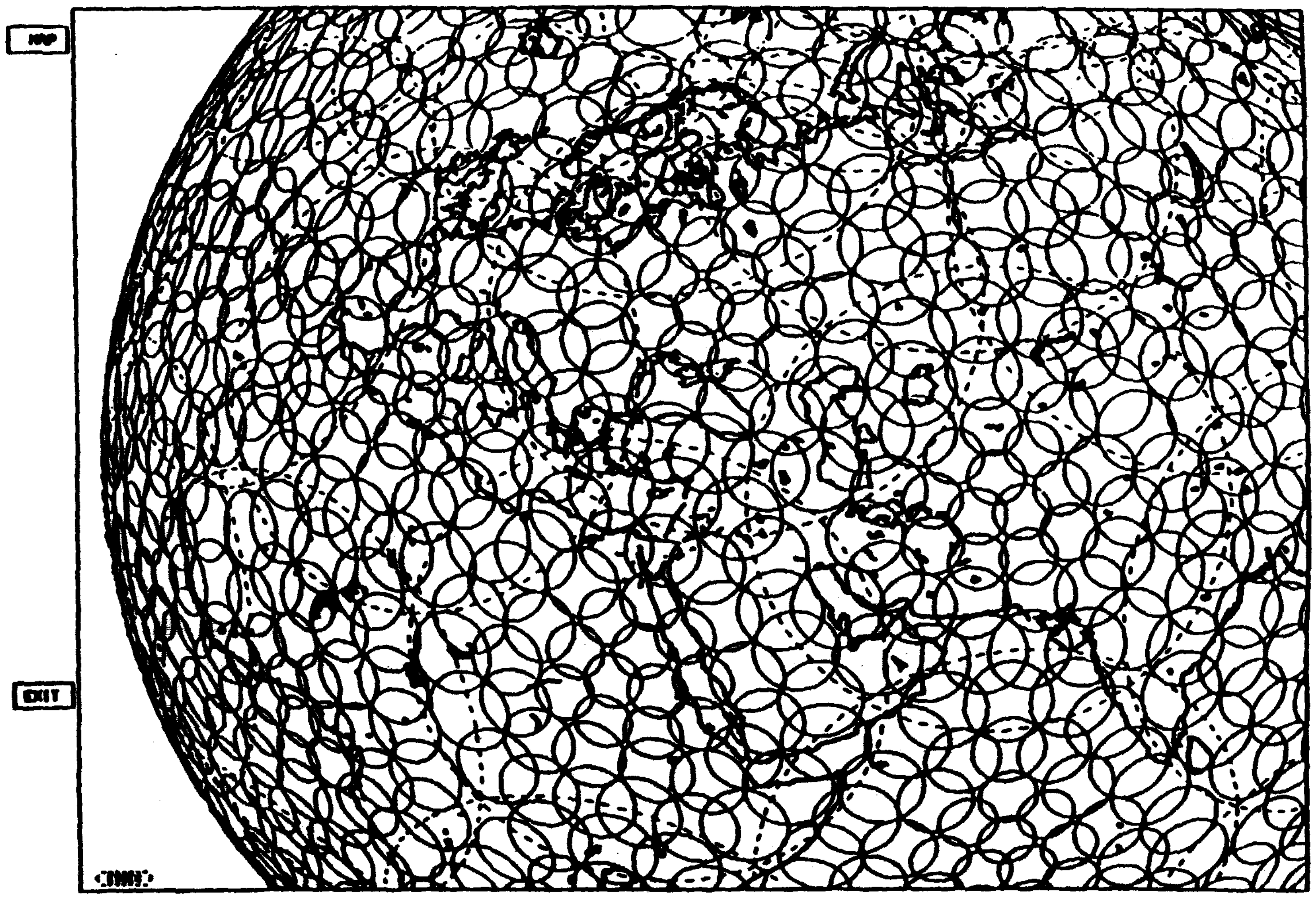
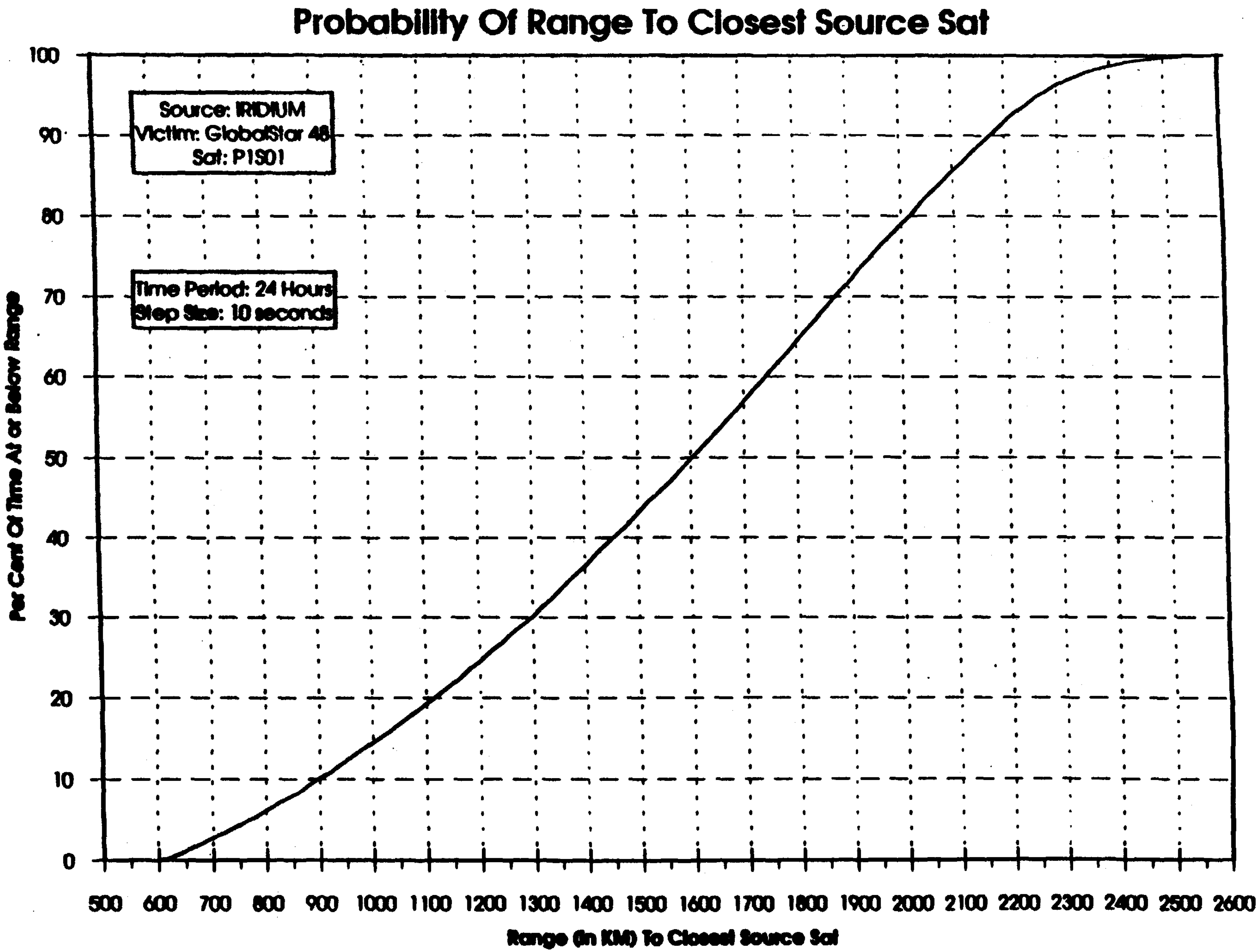


FIGURE 4.5-1: SPOT BEAM EARTH COVERAGE

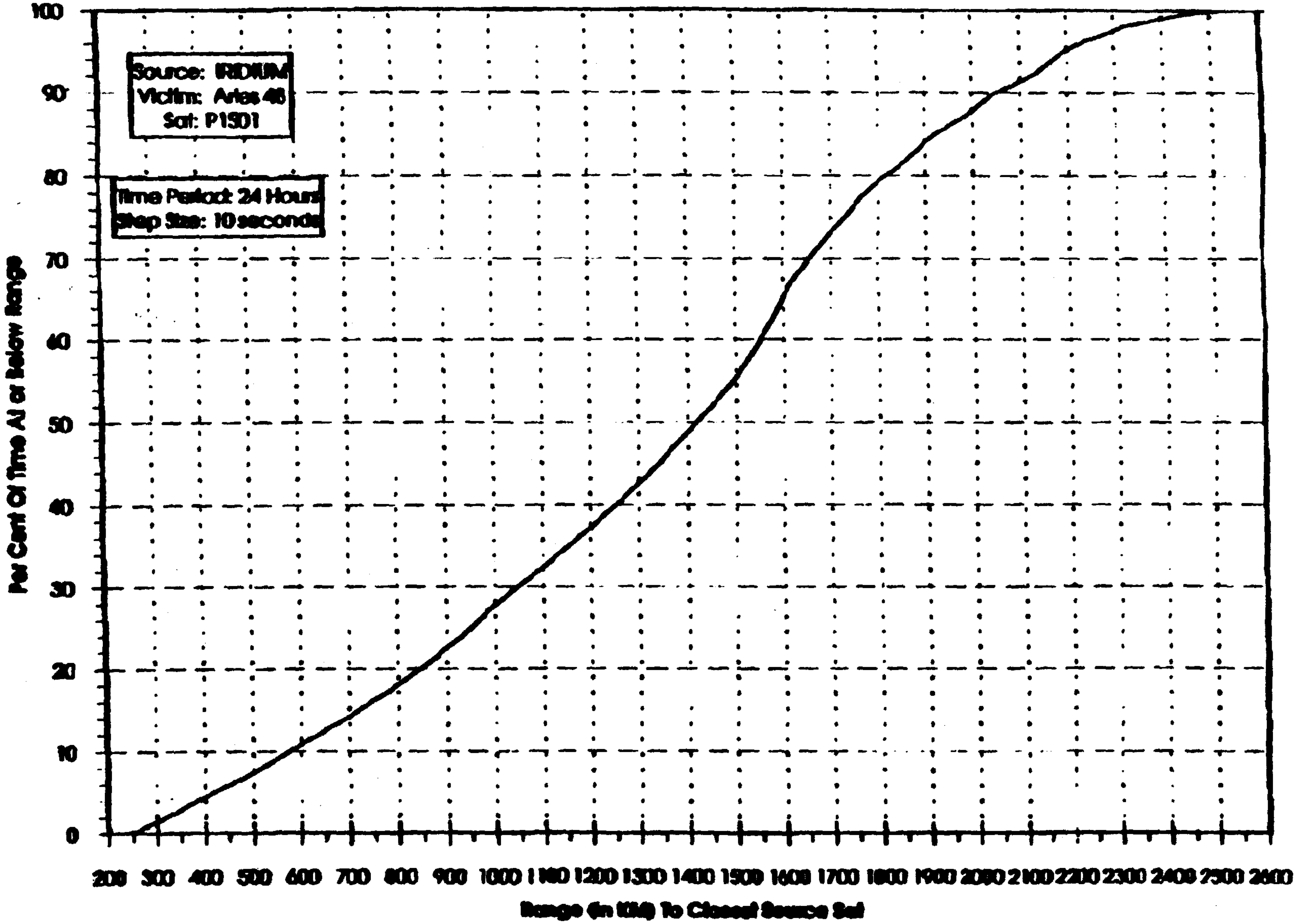


FCC_1BJXLC

FIGURE 4.5-2a

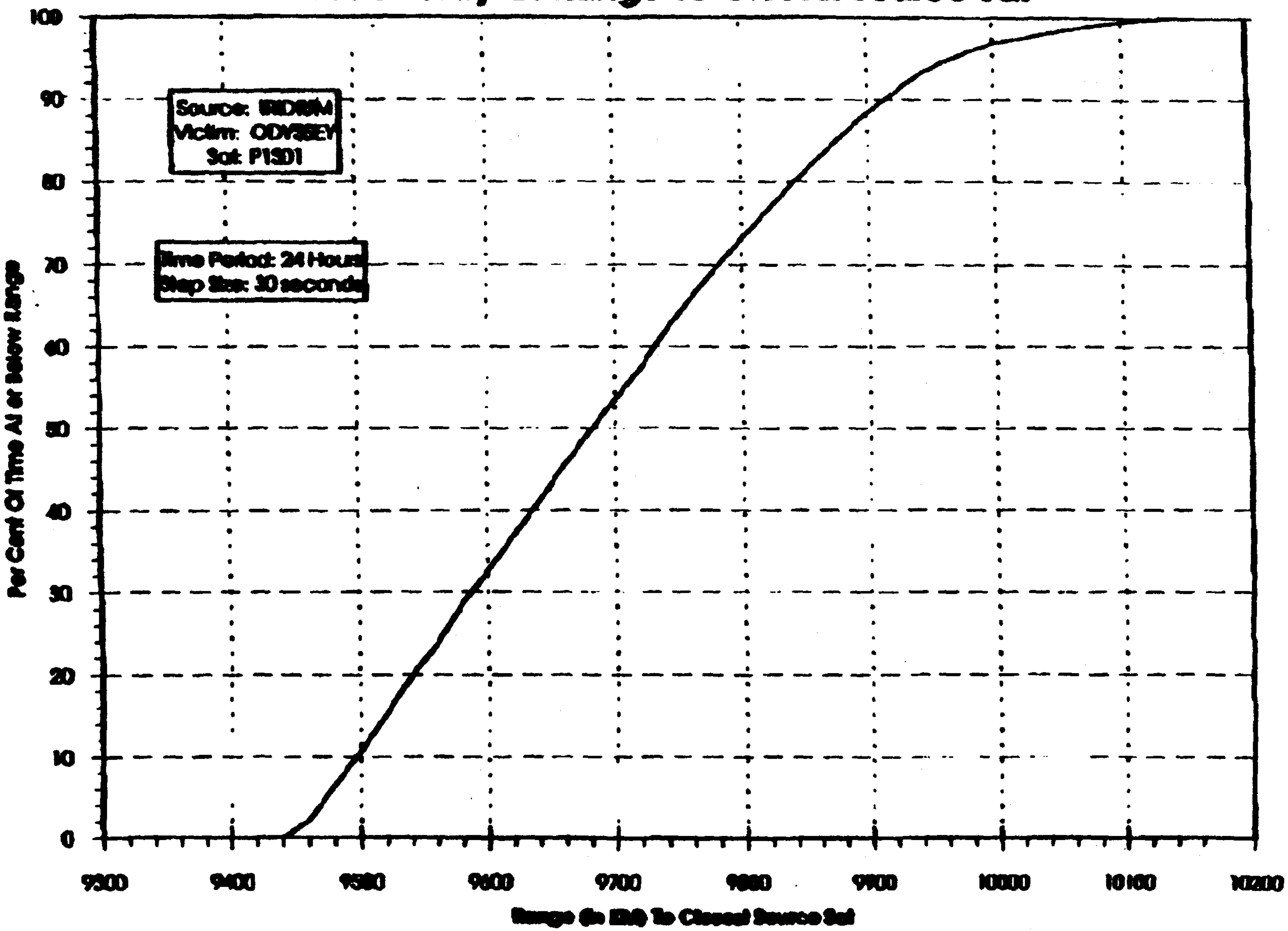
FIGURE 4.5-2b

Probability Of Range To Closest Source Sat



FCC 2B.KLC

FIGURE 4.5-2c **Probability Of Range To Closest Source Sat**



HCC_SB.XLC

would be caused to other MSS systems that would otherwise operate co-frequency in a portion of the band.

Figure 4.5-3 shows a typical scenario where frequency management may be utilized. This figure shows two systems operating in two separate bands in the U.S. A potential interference scenario could occur if the Iridium system has a larger frequency assignment in another coverage area than it does in the United States. This is defined as partial co-frequency. These coverage areas are expected to be very large. For example, the Iridium system may have a different bandwidth of operation in North America than South America, but Iridium's bandwidth operation in Canada is not expected to be different from the U.S. or Mexico.

Where the systems operate in different regions, the only potential interference scenario is the trans-horizon case. Although the two systems have different service areas, in this potential partial co-frequency interference scenario, the skirts of their trans-horizon beams may still intersect. These situations will need to be analyzed, on a case by case basis, to determine the potential for in-band harmful interference taking into account of the isolation of the antenna beams.

An example of how frequency management could be used to prevent harmful interference follows. Assume that the Iridium system is licensed to operate in a broader bandwidth in one part of the world than another. When the geometry of the satellites in their respective orbits is such that there is a potential for either trans-horizon or backlobe/sidelobe interference, the Iridium satellite could manage its frequencies so that there would be no co-frequency operation during the short period of interference susceptibility.

One frequency management technique uses the 6 beam reuse pattern of the Iridium system. In this reuse pattern, a frequency is repeated in every 6th beam. The frequencies may be managed so that they are not used in a beam where there is a potential for interference. This is especially useful in the trans-horizon scenario where main beam intercepts with Iridium outer beams are possible.

FREQUENCY MANAGEMENT

o Reduced cofrequency beam coupling under transhorizon geometries

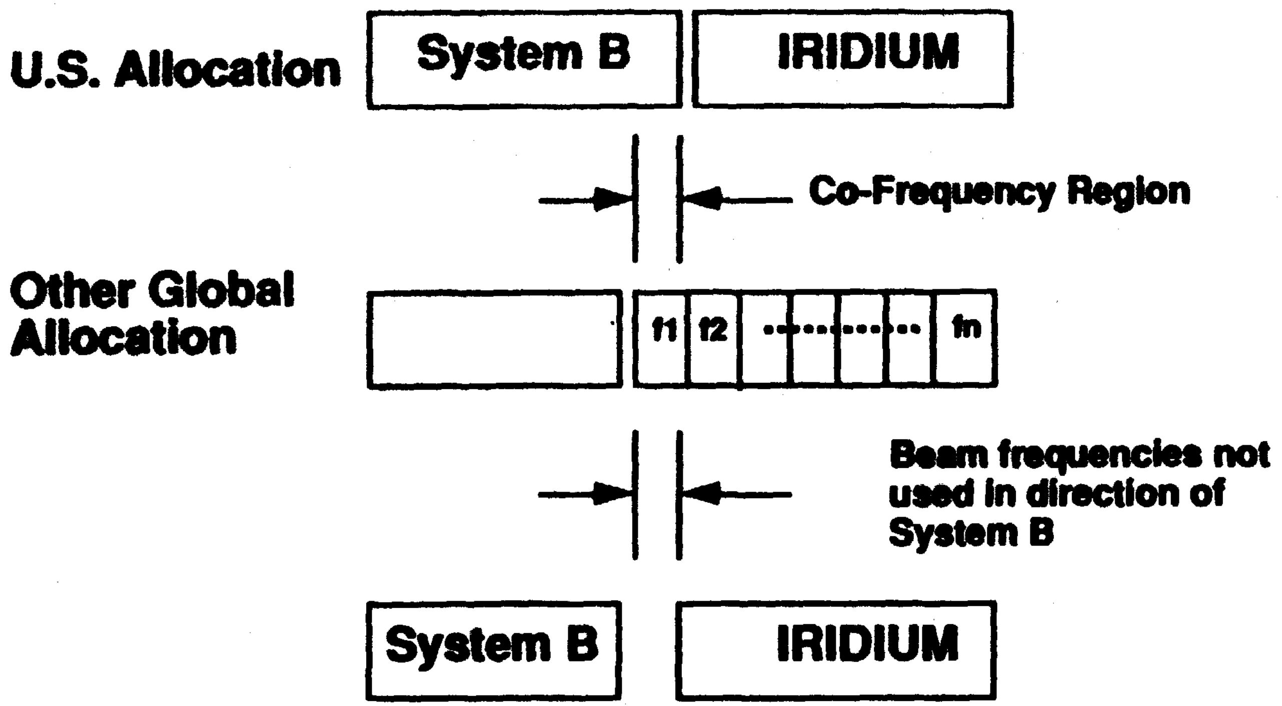


Figure 4.5-3 Frequency Management

4.5.1.4 Antenna Polarization Characteristics

If necessary, the antenna polarization between the interfering satellite systems can be selected to accommodate inter-system interference reduction once the characteristics of other MSS systems are fully designed. This would be accomplished during the initial coordination process between U.S. licensees. The systems would have to be circular polarized and therefore cross polarization isolation could only be achieved between individual pairs of systems.

4.5.2 Application of the Mitigation Methods

This section describes how the mitigation techniques may be used to eliminate the potential for harmful interference. The pre-mitigation interference numbers are taken from Tables 4.4-1 and 4.4-2 of Section 4.4. Table 4.5-1 summarizes the four interference geometries of concern and the techniques available to mitigate any potential mutual interference.

There is considerable flexibility in Motorola's Iridium system design. This flexibility will be used in coordinating its secondary downlinks worldwide. The flexibility is due to Iridium's controllable spot beams, FDMA/TDMA access techniques, and variable rate vocoder. The following sections indicate the impact of the above mitigation techniques on the interference calculations in Section 4.4.

4.5.2.1 Case 1 - Backlobe

Case 1 is defined as a situation in which the victim satellite #1 is in a higher orbit than the interfering satellite. In this case the minimum spacing between the satellites will be determined by the difference in orbit altitudes of the interfering and victim satellites. The potential interference is from the backlobe of the interfering satellite into the mainlobe of the victim satellite.

Table 4.5-2 shows the application of the mitigation techniques for the backlobe situation. The interference percentages are taken from Table II in the previous section. Out-of-band interference levels for Iridium are

35 dB below the in-band spectral power density. Backlobe geometries are almost always where co-coverage is taking place and band segmentation has been coordinated.

Table 4.5-2 - Backlobe

	Globalstar	Odyssey	Celsat	Aries	Ellipso
% Before Mitigation	4.6	0.9	3.8	7.9	0.9
Band Segmentation Attenuation (dB)	35	35	35	35	35
% After Mitigation	.001	.0003	.001	.002	.0003
Capacity Lost	0	0	0	0	0

As can be seen from this table, band segmentation completely resolves the problem and no channels are lost. No other mitigation technique is needed other than to operate in a different band than the other systems.

4.5.2.2 Case 2 - Trans-horizon

Case 2 is defined as when the victim satellite may be in any orbit. The characteristic of this case is that the potential interference path is just over the horizon of the Earth. Therefore, the potential interference may be from the mainlobe skirts of the interfering satellite into the mainlobe skirts of the victim satellite. The somewhat higher antenna gains for this interference link are usually significantly offset by the larger link distances involved.

Table 4.5-3 shows the application of certain mitigation techniques for the transhorizon situations.

Table 4.5-3 -Trans-Horizon

	Globalstar	Odyssey[5]	Celsat	Aries	Ellipso
% Before Mitigation	6.7	66.6	0.7	3.8	0.3
Frequency Management (dB)	35	35	35	35	35
Beam Management (dB)	20	20	20	20	20
Polarization (dB)	10	10	10	10	10
% After Mitigation	.01	.01	.01	.01	.01
Capacity Lost	0	0	0	0	0

The trans-horizon case requires two mitigation techniques to be used, frequency management and beam management. Polarization diversity may also be used where applicable. Use of these mitigation techniques completely resolve any interference concerns and no channels are lost.

4.5.3.3 Case 3-Adjacent Channel Interference

For all the geometries in the previous cases, the level of required mitigation reduction does not excede 35 dB. Therefore, adjacent channel interference from the secondary downlink never requires any other mitigation technique.

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5 Tilted case.

ANNEX 4.1

CURRENT (3/29/93) SYSTEM PARAMETERS USED IN ANALYSIS

CONUS Area= 7825000 Km^2; +Overlap of - 30%= 10172500 Km^2

	Aries	Ellipso	Globalstar	Odyssey	Celsat
Orbit Height;R (Km)	1020	3000 (min.operating)	1414	10370	38000
Number CONUS Beams	10	10	20	16	149
Beam Area (Km^2)	1017250	1017250	508625	635781	68272
4 PI R^2/Area	12.9	111.2	49.4	2125	265788
Antenna Gain (dB)	11.1	20.5	16.9	33.3	54.2
Angl.Boresite/Horiz(FI)	7	8	5	4	4
VicSat Ant.Gain For Tran-Horiz 29-25log(FI)	7.9	TEMPORARY VALUES 6.4	11.5	13.9	13.9
Uplnk EIRP Areal Density	-140	-140	-140	-140	-140
Sat Ant Beam Overlap Factor	1.00	1.00	1.23	1.25	3.80
IRID Backlobe to Victim Closest Path Length(Km)	261	2220	634	9591	35003
IRID Tran-Horiz to Victim	7039	10120	7726	18737	44925
Required Eb/NT	4.0	4.5	4.8	4.5	4.5

ANNEX 4.2
3/20/93
IR-CELP2

CALCULATION OF IRIDIUM AVERAGE DOWNLINK EIRP DENSITY

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Major Assumptions:

:IRIDIUM
Reuse Factor= 6
Backlobe Isol= 39 dB
Polariz Isol = 20 dB
Ant.Gain below EOC to Horizon = 5 dB

For Equator

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RING -->	1	2	3	4	Backlobe Weighted Average	X-Horizon Ring 1
No. Cells in Ring	21	15	9	3	NA	21
Min.EOC EIRP(dBW)	12.7	9.5	7.0	4.5	10.8	12.7
Watts	18.6	8.9	5.0	2.8	12.0	18.6
Elev Angle EOB	8.2	20.8	33.2	51.9	NA	8.2
Ave.Fade Req.(dB) per Fig 2 CCIR Propagation Paper(except Ring 1)	9.1	6.6	6.6	6.6		
Ratio Ave/EOC Gain (dB)	-0.1	-0.2	1.0	1.5	TEMPORARY VALUES	
Net EIRP (dBW)	21.7	15.9	14.6	12.6	19.2	21.7
Watts	147.9	38.9	28.8	18.2	83.4	147.9
Voice Activity Factor					0.375	0.375
Traffic Activity Factor					1.0	1.0
Average Downlink In-Band EIRP for Interf. Anal. (dBW)					15.0	17.4
Frequency Reuse Factor					6	1
Ave. Downlnk EIRP Dens. @ 41666 Hz Carrier Spacing Including Freq. Reuse (dBW/Hz)					-23.46	-28.76
IRIDIUM Sat. Antenna Discrimination (dB)					39	5
Polarization Isolation (dB)					0	0
Ave. Downlnk In-Band EIRP Dens. in Direction of Victim (dBW/Hz)					-62.46	-33.76

CALCULATION OF IRIDIUM AVERAGE UPLINK EIRP DENSITY

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RING -->	1	2	3	4	Backlobe Weighted Average	Worst Case Ring 1
No. Cells in Ring	21	15	9	3	NA	21
Min.EOC EIRP(dBW)	-7.2	-9.1	-11.8	-7.9	-8.4	-7.2
Watts	0.2	0.1	0.1	0.2	0.1	0.2
Elev Angle EOB	8.2	20.8	33.2	51.9	NA	8.2
Ave.Fade Req.(dB) per Fig 2 CCIR Propagation Paper(except Ring 1)	9.1	6.6	6.6	6.6		
Ratio Ave/EOC Gain (dB)						
Net EIRP (dBW)	1.9	-2.5	-5.2	-1.3	-0.2	1.9
Watts	1.5	0.6	0.3	0.7	1.0	1.5
Voice Activity Factor					0.500	0.500
Traffic Activity Factor					1.0	1.0
Average Uplink In-Band EIRP for Interf. Anal. (dBW)					-3.2	-1.1
Frequency Reuse Factor					6	1
Ave. Uplink EIRP Dens. @ 41666 Hz Carrier Spacing Including Freq. Reuse (dBW/Hz)					-41.62	-47.31

ANNEX 4.3

Interference Assessment of Secondary Downlinks by CDMA Applicants

The CDMA applicants have put forward an analysis of the potential for interference from in-band secondary downlinks to primary uplinks. This analysis considers the effect of in-band interference on each of the CDMA systems in isolation. That is, the analysis ignores the presence of interference from other in-band primary uplink carriers and assumes the victim is subject only to its own self-interference and that of the secondary downlink. Thus, the analysis provides misleading results since it does not take into account the true interference environment of the victim satellite receiver. A realistic environment will impose uplink signals from all the co-existing, co-frequency, co-coverage systems on the victim system. As was shown in Section 4.4, when all co-existing primary uplink interferers are taken into account, the interference contribution of in-band secondary downlinks is almost always negligible in a real sense.

Moreover, one of the basic premises of the analysis of the CDMA applicants is the assumption that there is only one mitigation method for the increase in the interference density of a victim uplink due to in-band secondary downlinks. That single mitigation method is claimed to be a reduction of the capacity of the CDMA system. In fact, there are several other mitigation methods. Several mitigation methods are outlined in Section 4.5. Others include:

- reduction in the traffic carried by the secondary downlink

- "benign neglect," because the reduction in link performance (Eb/N_T) of the victim uplink does not sufficiently degrade the bit error rate of the voice signal to constitute harmful interference.

The analytical method employed by the CDMA applicants starts with a determination of the interference EIRP density of the secondary downlink as well as the EIRP density of the minimum desired uplink signal at the victim satellite. This assessment of the effect of the secondary downlink is based on the erroneous concept that CDMA communications system capacity is based on the sharing of interference caused only by users of the victim CDMA system. The effect on capacity caused by other co-frequency CDMA systems is ignored in this concept. Thus the analysis of the CDMA applicants assumes, without explanation, that any additional interference due to secondary downlinks will detract only from the interference allowance of the users of the victim system and thereby detracts capacity only from the victim system. In putting this concept forward, the CDMA applicants are also making several other unstated and unwarranted assumptions about other mitigating methods, system loading, power control capability, link performance and user satisfaction, demodulator and vocoder capability and other factors. The analysis of the CDMA applicants also assumed the interfering power will displace the self-interference noise otherwise allocated to only the minimum power users of the desired system (but not the average or high power user) -- thereby reducing the capacity of the system by an equivalent number of only minimum power circuits. Neither the analytical approach, nor its implementation, nor the assessment criteria, is appropriate for "real-world" systems or a realistic environment.

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IRIDIUM - ELLIPSO COUPLING DUE TO PRIMARY UPLINKS AND REFLECTIONS OF THE SECONDARY DOWNLINK

1. INTRODUCTION

This brief paper is a description of the level of primary uplink signals and the associated secondary downlink signal reflections from the earth. The analysis is based on the example of the IRIDIUM and the ELLIPSO Low Earth Orbit (LEO) satellite communications systems. An in-depth analysis of the subject requires detailed system parameter information and detailed characteristics of the reflection parameters. All of the information and parameters are not available at this time. For this reason the subject of coupling between the two systems can only be treated in a generic fashion. However, it is believed that sufficient data is available to provide a general conclusion.

The ELLIPSO LEO system is intended to provide communications over the Continental United States (CONUS) by forming a group of eight circular shaped beams to service the 48 state area. The uplink employs CDMA modulation which spreads 9.6 kbits of information over a channel of 1.1 MHz. ELLIPSO satellites operate at a nominal altitude of 4000 km above the surface of the earth.

The IRIDIUM system provides communications on a world-wide basis using spot beams averaging 400 km in diameter. Approximately 59 beams provide service to the CONUS. The TDMA/FDMA modulation is single channel per carrier spaced 41.67 kHz apart. The occupied channel bandwidth is 31.5 kHz. Transmission of data is bi-directional between earth subcriber units and their companion satellite. IRIDIUM satellites operate at a nominal altitude of 780 km above the surface of the earth.

2 INTERFERENCE CONSIDERATIONS

2.1 Band Segmentation

Co-frequency, co-coverage operation between an interference sharing (CDMA) and a narrow band (TDMA/FDMA) is impossible due to the interference received by the FDMA/TDMA system. Country by country frequency assignments creates problems due to the beam sizes of the satellite antennas. The IRIDIUM system will generally seek common frequencies throughout an ITU region . However, certain circumstances exist where flexibility in frequency assignments may be possible, i.e. different assignments could be considered between the continents in Region 2.

2.2 Subcriber Units, Uplink Path

The primary interference path of concern is the uplink path to the ELLIPSO satellite from IRIDIUM subcriber units. The ELLIPSO subcriber unit produces a PFD of -199.9 dBW/m^2/Hz at the ELLIPSO satellite The IRIDIUM subcriber is capable of producing an effective PFD of -243.3 dBW/m^2/Hz when demodulator spreading is considered. An assemblage of IRIDIUM subcribers which fully loads a single ELLIPSO channel could increase the PFD at an ELLIPSO satellite to approximately -226.0 dBW/m^2/Hz. Calculations to support these PFDs are contained in Appendix A of this paper.

2.3 Reflection Path

A second interference path is earth surface reflections of energy from an IRIDIUM satellite beam back to an ELLIPSO satellite antenna. While an infrequent event of lesser magnitude, the subject is evaluated in Appendices A with supporting information in Appendix B of this paper.

A reflection path between and IRIDIUM satellite and an ELLIPSO satellite is complex. The geometry of the two satellites must be considered as well as the statistical properties of the reflected signal. Considering first the properties of the earth as a reflector, a number of investigators have shown that the earth is rough at L-Band (see Appendix B). Hence the earth acts as a scatterer of radiation more so than a spectral mirror. The loss figure used by industry for diffuse scattering is -10 dB. To this must be added at least another -3.0 dB to account for beam divergence. These values apply at all times over land surfaces and 99+% of the time for large bodies of water. A large body of water the size of Lake Superior needs to have wave heights of less than a few centimeters to be considered a spectral mirror.

The IRIDIUM satellite is capable of producing through reflections an effective per channel PFD of -245.5 dBW/m^2/Hz at the ELLIPSO satellite when demodulator spreading is considered. A set of IRIDIUM subscribers fully loading a single ELLIPSO channel could increase the PFD at an ELLIPSO satellite to approximately -228.0 dBW/m^2/Hz. Calculations to support these PFDs are contained in Appendix A of this paper.

3. CONCLUSION

Harmful interference to the ELLIPSO system begins when the sum of all interference, including self and other system interference, reduces the bit error rate to less than an acceptable level. The ELLIPSO system is portrayed as being able to tolerate many interfering signals, i.e. 15 ELLIPSO equivalent signals, within a channel. This tolerance has a "soft knee" characteristic, i.e., a slight increase in interference causes a slight increase in bit error rate which results in a slight decrease in voice quality. A "hard knee" would require a reduction of channel capacity. Channel capacity reduction is not required by the ELLIPSO system if the increase in bit error rate is minimal.

A full load set of IRIDIUM primary uplinks produce the equivalent of 0.0022 ELLIPSO channels. The corresponding downlink reflections produce the equivalent of 0.0013 ELLIPSO channels. The combination of these signals causes a negligible increase in the ELLIPSO bit error rate.

So long as IRIDIUM and ELLIPSO do not operate co-channel, interference to ELLIPSO will not cause harmful interference. A band segmentation of frequency assignments between the two systems would permit sharing of the 1616.0 - 1626.5 MHz band.